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Changes of Soil Properties on Various Ages of Rubber Trees in Dhamasraya, West Sumatra, Indonesia

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ABSTRACT

Changes of Soil Properties on Various Ages of Rubber Trees in Dhamasraya, West Sumatra, Indonesia (S Yasin, Adrinal, Junaidi, E Wahyudi, S Herlena and Darmawan): Although rubber has been planted in Indonesia from Holland era, but there is little information about the effect of rubber plantation on the rate of land degradation in Indonesia. In order to examine the effect of rubber tree (*Hevea brasiliansis*) ages on land degradation status, a series experiment was done in Dhamasraya district as the main contributor of natural rubber in West Sumatra, Indonesia. Study site divide into forest (A), crab grass (B), and rubber plantation with ages ranged from 1 (C), 5 (D), 10 (E), 15 (F) and 20 (G) years were selected as study sites and soil samples had been taken from each site, where forest soil was used as a control. The result proved that the age of rubber tree has strongly affected physical and chemical properties of soil. Organic carbon and total nitrogen content decreased from 3.02%, 2.66%, 1.96%, in site A, B and C, and then increased to 2.33% and 2.49% in site D and E, respectively. This result was opposed with bulk density (BD) value of each site. The highest BD found in site C (1.26 g cm^{-3}), followed by site D, E, B and A with 1.24, 1.14, 1.12 and 0.88 g cm^{-3}, respectively. The similar pattern was also found for selected chemical properties of soil. Soil pH, available phosphorous, exchangeable base cations, cation exchange capacity and base saturation was likely to decrease from 1 to 10 years old plantation and then increased close the natural condition (reflected by forest soil) at 20 years old rubber tree. Since most of plantation was conversed from natural forest, this phenomenon might be because of contribution of organic matter from original condition and addition of fertilizer at the beginning of plantation establishment.

Keywords: Bulk density, cation exchange capacity, rubber tree, soil properties

INTRODUCTION

Forest is the most stable ecosystem in the earth. Hydrology and nutrient cycle in forest can protect the forest ecosystem from drought and nutrient insufficiency. Returning of organic matter through leaves fall and branches decomposition supply forest soil with adequate nutrient which make the nutrient cycling within the forest ecosystem almost balance (Jordan 1985; Wilcke *et al*. 2001). This condition put forest ecosystem as parameter and control for the soil fertility changing in other ecosystem (Donald 2003).

Dhamasraya district is the one of rubber plantation center in West Sumatra which contributes more than 50% of total crumb rubber production from this province. Although some of these plantations are very old, but there are a lot of new rubber trees are planted on this area. The expanding of rubber plantation in this district was triggered by the blooming of rubber price in the global market. Deforestation and land use change from other agricultural purposes to rubber plantation are common problem in this area, which potent to create some ecological problems such as decreasing in biodiversity, hydrological cycle disturbance, and increasing rate of organic matter decomposition, accelerate erosion process, degradation on physical and chemical of soil properties (Yasin 2004; Irwan *et al*. 2008).

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Even though the above activities create some adverse effect on soil and environment as well, there is no empirical data show the consequences of deforestation and the various ages of rubber plantation on the change of physical and chemical characteristic of soil.

The main purpose of this research was to examine for the effect of various ages of rubber plantation in the changes of soil properties in Dhamasraya district, West Sumatra Indonesia.

MATERIALS AND METHODS

Study Site and Sampling

In order to reach the study purpose, study sites were selected in Dhamasraya district, West Sumatra Indonesia. To examine the effect of various ages of rubber plantation on the changes of soil properties, study site group into forest (A), crab grass (B), and 1, 5, 10, 15 and 20 years old rubber plantation consider as C, D, E, F and G plot, respectively.

Soil Analyses

Air-dried soil samples were ground and passed through a 2-mm sieve. Soil pH was measured by using a glass electrode method with a soil: water ratio of 1 : 2.5 (IITA 1979; Mclean 1965). Exchangeable base cations (Ca, Mg, K and Na) were extracted by 1 M neutral ammonium acetate (Thomas 1982) and then exchangeable Ca and Mg were determined by using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Shimadzu ICPS 2000). Exchangeable K and Na were determined by Atomic Absorption Spectrophotometer (Shimadzu AS 680) and bulk density (BD) by gravimetric method. Total carbon and nitrogen were determined by the dry combustion method (Nelson and Sommers 1982) using a Yanaco CN Corder Model MT-700 (Yanagimoto MFG. Co., Kyoto, Japan). Available P was extracted using the Bray 2 method and the content was determined by colorimetry with an UV/VIS Spectrophotometer (Jasco V-530, Tokyo, Japan) (Bray and Kurtz 1945).

RESULTS AND DISCUSSION

Effect of Various Land Uses on Some Physical Properties of Soil

Table 1 shows the effect of rubber trees ages on the physical properties of soil in the study site. The change of pattern of soil bulk density in top soil layer (0 -20 cm) found different than in sub soil (20 – 40 cm) (Figure 1). In top soil layer, soil bulk density increased from A (forest) to D (5 years old of rubber tress) and then gradually decreased until G plot, with value closed to forest. Although in sub soil the general pattern of bulk density found similar, but the highest value found in E and then slightly decreased up to plot G. The difference of bulk density value in top soils and sub soil of forest as original soil was smallest as compare to other land uses and the widest gap was found in C plot (Figure 1).

The discrepancies of soil physical properties were correlated each other. The changes pattern of soil bulk density has an opposed trend compared to soil organic matter (SOM) content (Figure 2). Although plot C has the lowest bulk density value, but it seemed that it was affected strongerly by land preparation which disturb or somewhat destroy soil structure which created more porous soil layer (Guggenberger *et al.* 1994). Generally, increasing of SOM content clearly affected the bulk density value in all plots studied. The highest SOM content was found in A plot (4.84%) follow by G plot (4.59%) (Table 1). These results indicated that in peculiar circumstances, rubber plantation could recover soil

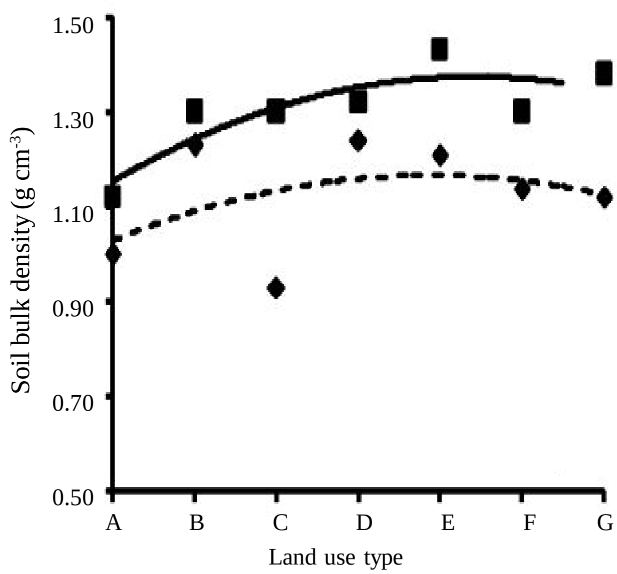

Figure 1. The change of pattern of soil bulk density as affected by land use type in top soil (♦ = 0 - 20 cm) and sub soil layer (■ = 20 - 40 cm). A = forest, B = crab grass, C = 1 year old rubber tree, D = 5 years old rubber tree, E = 10 years old rubber tree, F = 15 years old rubber tree, and G = 20 years old rubber tree.

to original condition. Stott *et al.* (1999) report that cultivation processes without organic matter addition would accelerate the increasing of bulk density due to declining of soil organic matter. Therefore, soil solid phase would be dominated by minerals which changed the composition of soil as whole. Brady and Weil (2002) stated that soil texture also acted as an important factor to determine soil bulk density.

Within the top soil, the highest value of total C-organic was found in plot C (1 year old of rubber plantation) (3.07 %) while the lowest was in plot E (10 years old) (1.96%). Although there was no discrepancies found between the land uses types, this condition might related returning process of organic matter from forest floor. The change of land use from forest to crab grass decreased C-organic content in soils. Re-planting of the land with rubber tree could recover the C content in soil significantly. Yasin (2001) reported that forest is the most stable and sustainable ecosystem which able to supply nutrient by themselves.

The carbon content in soils increased when forest was converted into rubber tree until 1 year. After that C content decreased gradually to 10 years and again increased when rubber tree reached 20 years old. Increasing of C content on 20 years old rubber plantation was related to returning of biomass through leaves and branches which decomposed in site of the land. The C content in sub soil layer (20 – 40 cm) generally followed the trend in top soil with the total content was lower than in top soil.

Data in Table 1 also presents the effect of land use type on soil particle distribution. The sand content increased sharply as land use changing from forest to other purposes. The highest sand content was in plot B (33.44%) followed by E and F plot with 25.99% and 25.08%., respectively, while the clay content was in the inversed trend. It indicated that as the finest soil particle, the clay gradually washed out from soil layer as land cover was reduced by converting forest to rubber plantation. The changed pattern indicated the decreasing of clay content particles due to leaching that from the top to the deeper soil layer. We expect it might affect acceleration of erosion during land preparation activity. Forest, in one side, has a high ability to protect soil surface from the raindrop force, and keeps clay particles in a high percentage (36.12%). This result was in agreement with Zhang *et al.* (1997) which found that the erosion rate was affected by land use changed and aggregate stability.

Table 1. The effect of land use type on some physical properties in top soil and sub soil in Dhamasraya, West Sumatra, Indonesia.

Land Use	Soil layer (cm)	Particle distribution (%)			Soil texture	Bulk density (g cm^{-3})	Org-C (%)	Total-N (%)	SOM*
		Sand	Silt	Clay					
Forest (A)	0-20	12.29	51.60	36.11	SCL	1.00	2.81	0.15	4.84
	20-40	16.30	46.70	37.70	SC	1.12	2.12	0.12	3.65
Crab grass (B)	0-20	33.44	48.04	18.52	SCL	1.23	3.07	0.15	3.78
	20-40	13.80	48.52	33.00	SC	1.30	2.19	0.11	3.64
1 year (C)#	0-20	21.81	51.71	26.48	SCL	0.93	3.02	0.22	3.37
	20-40	18.12	47.97	33.91	SCL	1.30	2.26	0.16	3.90
5 years (D)#	0-20	24.01	48.04	27.95	SCL	1.24	2.66	0.19	4.02
	20-40	21.22	46.96	31.82	CL	1.32	1.50	0.09	2.59
10 years (E)#	0-20	25.99	51.25	22.76	SL	1.21	1.96	0.12	4.20
	20-40	24.56	49.81	25.63	CL	1.43	1.38	0.11	2.37
15 years (F)#	0-20	25.08	51.03	23.89	SCL	1.14	2.33	0.15	4.29
	20-40	11.37	55.92	32.71	SCL	1.30	1.85	0.12	3.18
20 years (G)#	0-20	24.72	48.41	26.87	SCL	1.12	2.49	0.15	4.59
	20-40	16.70	45.58	34.72	SCL	1.38	1.97	0.11	3.40

* = soil organic matter, # = rubber trees age, SCL = silty clay loam, CL = clay loam.

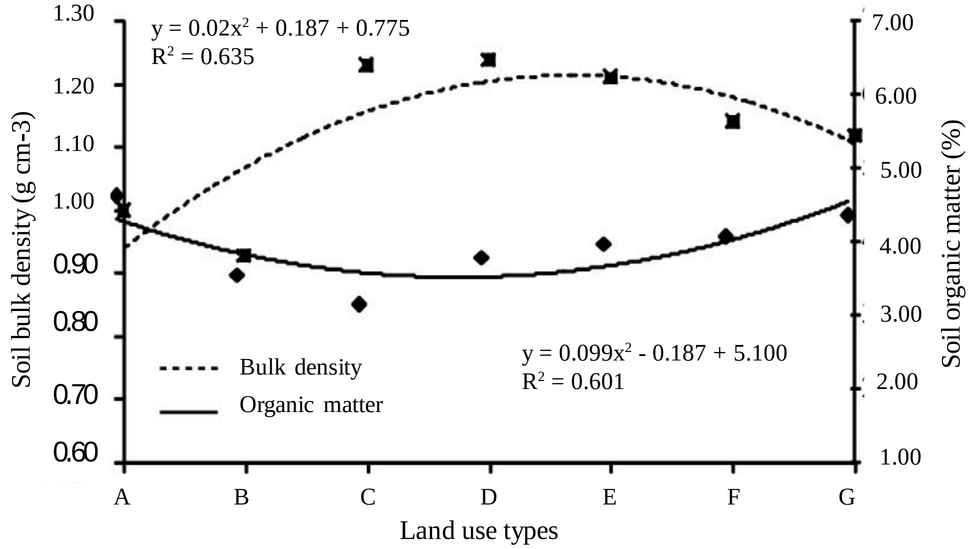

Figure 2. The relationship between the change pattern of bulk density and organic matter content of soil in some land use type in Dhamasraya, West Sumatra. A = forest, B = crab grass, C = 1 year old rubber tree, D = 5 years old rubber tree, E = 10 years old rubber tree, F = 15 years old rubber tree, and G = 20 years old rubber tree.

Brady and Weil (2002) stated that raindrop had three roles on erosion process. First, detaching soil particles, second destroying soil aggregates and third transporting agent of soil particle through run-off. Land use changed from forest to rubber plantation altered the density and diversity of trees caused by declining the density of land cover. Since the land surface remained with insufficient cover, the rate of erosion and run off raised and facilitated the transportation of the clay particle despite of sand.

Effect of Various Land Uses on Some Chemical Properties of Soil

The changes of soil physical properties altered the chemical character of soil (Table 2). As the finest particle, clay play an important role in chemical reaction in soil. Tan (2001) stated that clay mineral (clay colloid) acted as an important key factor in soil physics and chemistry as well. Its act as dominant factor for 1) determine the reaction in soil, 2) verify physical characteristic of soil related with soil texture, structure, aeration and drainage, 3) can be used as rate of weathering indicator, 4) soil classification parameter, and 5) control the fertility of soil as a whole.

The exchangeable aluminum (Al) content was influenced by land use type (Table 2). The highest exchangeable Al content found in B plot (crab grass) (2.78 $cmol_c$ kg^{-1}) whiles the lowest was found in C plot (1 year old rubber plantation) (2.36 $cmol_c$ kg^{-1}) (Table 2). The Al saturation on the other hand, was higher in crab grass and was significantly different with 1 and 20 years old rubber plantation. These results indicated that natural soil chemical properties were influenced by land use type and the form of land cover. Since the characteristic of 20 years old rubber tree was similar to natural forest, it would improve the recovery of soil chemical properties. Yasin (2001) and Hermansah *et al.* (2002) stated that the soil chemical characteristic in forest ecosystem was influenced by kind and size of trees and trees canopy. Because the 20 years old rubber tree had these two characters, the chemical condition under this ecosystem were similar to natural forest.

The high content of exchangeable and saturation of Al in crab grass site was correlated to leaching process of base cations to the deeper layer of soil. Since the soil was not fully cover by the crab grass, the rain drop hit the soil surface directly. This condition enhanced intensive leaching process of base cations as compare to another land uses type. In general, however, the content of exchangeable Al in all land use type was belonging to high category, including forest. According to Meng *et al.* (2001), the erosion rate is highly influenced by the land use system and land cover type. Under the similar climatic

Table 2. The effect of land use type on the changes of some chemical properties of top soil (0 - 20 cm) and sub soil (20 - 40 cm) in Dhamasraya, West Sumatra, Indonesia.

Land Use	Soil layer (cm)	Soil pH		CEC* (cmol kg^{-1})	Exch. base cation (cmol kg^{-1})				Avail-P (mg kg^{-1})	Exch. Al (cmol kg^{-1})
		H2O	KCl		Ca	Mg	K	Na		
Forest (A)	0-20	4.81	4.05	11.50	0.65	0.21	0.48	1.36	39.97	2.40
	20-40	4.61	4.02	12.75	0.75	0.14	0.40	1.38	37.25	1.90
Crab grass (B)	0-20	4.23	3.74	14.25	0.42	0.32	0.48	1.34	35.27	2,78
	20-40	4.19	3.93	8.50	0.45	0.18	0.55	1.55	31.00	2.45
1 year (C)#	0-20	4.42	3.76	14.88	0.77	0.35	0.70	1.65	45.08	2.35
	20-40	4.26	3.90	17.25	0.75	0.21	0.52	1.45	39.01	2.33
5 years (D)#	0-20	4.39	3.75	14.50	0.64	0.33	0.50	1.29	42.05	2.60
	20-40	4.48	3.99	12.38	0.52	0.15	0.41	1.60	27.74	2.55
10 years (E)#	0-20	4.17	3.80	10.75	0.60	0.16	0.40	1.40	40.68	2.79
	20-40	4.68	3.80	8.88	0.53	0.13	0.39	1.69	25.80	2.45
15 years (F)#	0-20	4.26	3.87	17.88	0.68	0.16	0.41	1.41	39.67	2.68
	20-40	4.47	3.93	11.63	0.48	0.13	0.41	1.70	28.27	2.15
20 years (G)#	0-20	4.72	4.02	14.00	0.76	0.16	0.43	1.55	39.98	2.45
	20-40	4.68	3.90	33.63	0.45	0.13	0.44	1.70	27.96	2.20

* = Cation exchange capacity, # = rubber trees age.

factor and soil type, the lands which were covered by small trees canopy or crab grass were easier to be eroded compare to the land with a good canopy covering capacity. Tan (2001) reported that tropical forest had acid reaction as effect on intensive leaching process which might affect the solubility of Al in soil.

The highest pH value was recorded in plot A (forest) (4.81) while the lowest was in crab grass (4.42) and the pH value of these two sites was significantly different. Since the study site was dominated by Ultisols, the low pH value in this location was understandable as this soil type belong to highly weathered and old soil (Jordan 1985). This condition was resulted by high content of Al in soil solution as the determinant factor of soil pH. Jordan (1985) stated that tropical soil had low pH as result of domination of Al cation and washing out of base cation.

This study found that soil pH increased following by the age of rubber plantation; however the differentiation between land use types was inconsiderable. This result indicates that decomposition product of organic matter such as organic acids in soil also can play a role as soil pH regulator. The changes pattern of soil pH was pposed with exchangeable Al content in soil (Figure 3). The soil reaction increased as decreasing of exchangeable Al. Maas *et al.* (1988) stated that soil reaction always had similar trend with exchangeable Al content in soils. Soil with acid reaction tended to have high content of exchangeable Al.

The average nitrogen (N) content in soil was varied among the plot. Generally, the N content was negligible among land use types, except for crab grass as low organic matter input to the soil. The trend of N content in soil was similar with C, where accumulation of N was much higher in top soil (0 – 20 cm) than in sub soil (20 – 40 cm). This research finding was in agreement with Darmawan *et al.* (2006); Sombroek *et al.* (1993), found the nitrogen and carbon content in the soil were mostly accumulated in the surface soil layer.

The similar trend was also found for available phosphorous (P) content in soil in crab grass; however there was no big different among the land use types, except for 1 year old rubber plantation. Available P content was recorded high in forest, 1 and 20 years

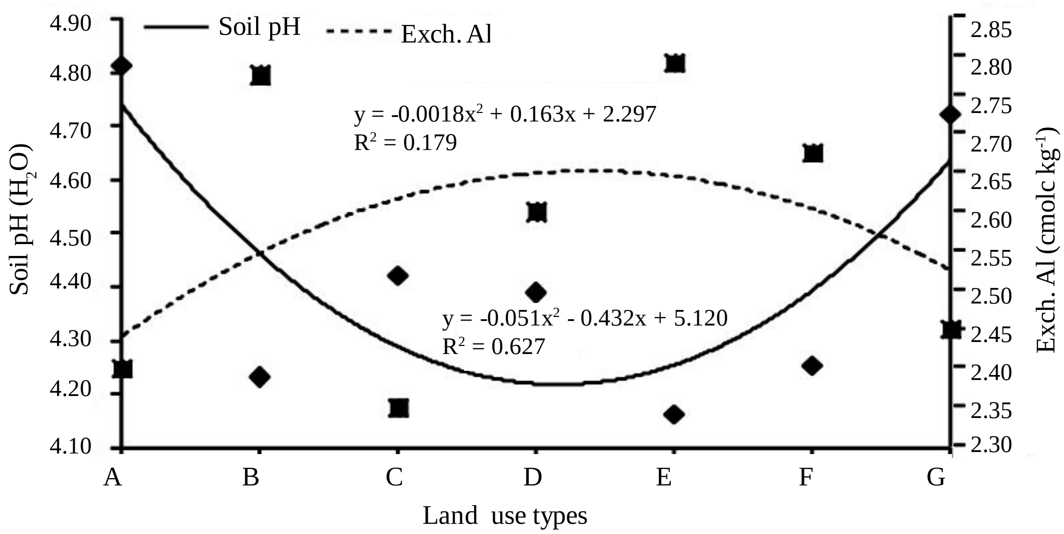

Figure 3. The change pattern of soil reaction reverses the exchangeable Al and found affected by rubber trees ages in Dhamasraya, West Sumatra.A = forest, B = crab grass, C = 1 year old rubber tree, D = 5 years old rubber tree, E = 10 years old rubber tree, F = 15 years old rubber tree, and G = 20 years old rubber tree.

old rubber plantation, which was related to contribution of organic matter into the soil which was able to improve organic P content in soil. Sanchez (1976) stated that perennial tree had ability to create close cycle of nutrient within themselves. Ripening of leaves and branches might protect the nutrient loss from soil. Brady and Weil (2002) stated that some parts of P soil belong to organic portion, and this organic fraction will be mineralized by microorganism to become inorganic form which will be available for plant.

This study found that the average content of exchangeable base cation was different among the land use type without any clear pattern. The highest content of exchangeable Ca, Mg, K and Na found in plot C (1 year old rubber plantation) (14.88 cmolc kg^{-1}), while the lowest was in crab grass. Tropical climate with high precipitation resulted in intensive leaching process of base cation. Brady and Weil (2002) stated that Ultisols characterize by low content in base cations and pH. The base cation content in crab grass related to forest clearing processes which change the land covering pattern and somewhat reduce the top soil layer. This result indicated that standing pattern and canopy covering of trees affected the leach out of nutrient from the land. Sanchez (1976) said that decreasing of base cation content in soil was much faster in intensive land cultivation than in bare land or forest.

The value of CEC in 1 year old rubber plantation was similar to forest and significantly different with crab grass. This condition was correlated to low content of organic matter and clay as presented in Table 4. Organic matter played an important role to determine the CEC value of soil as it had high ability to absorb cations and also humus as the main constituent of organic matter with highest CEC value as compare to other materials. Because of this, the CEC value had similar pattern with organic matter content in soil. Tan (2001) noted that in acid soil, colloid would hold tightly the nutrient ion, created the lower CEC value in soil. Sanchez (1976) also said that shifting cultivation wiould change soil pH and soil organic matter, and indirectly affected the CEC content of soil. The CEC value of soil was not just depend on pH and organic matter, but also influenced by soil texture, especially the clay content. CEC had a positive correlation with clay content of soil, because the finer texture had bigger specific surface which could hold more cations to increase the CEC value of soil.

CONCLUSIONS

The physical and chemical characteristic of soil were affected by the land use type. The changes of patterns were influenced by human activities such as land preparation and cultivation processes. The general data indicated, the rubber plantation has a capability to recover soil to original condition in both physical and chemical properties. It can be concluded that proper management of rubber plantation could minimize the land deterioration and maintained soil under good conditions.

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